On the origin of species information systems: an evolutionary perspective

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Introduction
This article covers the origin and development of animal record-keeping in zoos and aquariums, and the evolution of the International Species Information System (ISIS). With the escalating loss of species biodiversity in the natural world, zoological institutions today play an increasingly important role in conservation, both ex situ and in situ. Only careful scientific management of populations under human care will preserve the genetic and demographic diversity essential for successful sustainable maintenance. Accurate records-keeping is critical for the long-term management and stability of these populations. Sound records kept (and pooled) on animal populations can be analyzed for the long-term management and conservation goals.

Evolution of Animal Records-Keeping
Precise, cooperatively managed and shared animal records-keeping is a relatively new electronic process that has evolved into a sophisticated global data set on wild animals held ex situ. The evolution of records-keeping runs parallel with the history of zoological institutions, as they developed from menageries towards being conservation centres. Few animal collections kept proper records when the first zoos were established in the late 17th and early 18th centuries. By the mid to late 18th century, basic animal acquisition and disposal information were sometimes kept in large ledger books (see Ledger pictures). More elaborate written records were kept in logbooks, primarily for archival purposes rather than applied animal management use. In the early years of many zoos and aquariums, most animals were acquired from the wild and breeding was infrequent. Animal husbandry techniques were not well established and animals had short life spans, sometimes living for only a few months after arrival at the zoo. The only information generally available was basic livestock census statistics. In 1962, Marvin Jones, a founding member of the Zoological Registrars Association (initially titled Zoo Registrars Group) in North America, created the first census of rare animals in American zoos (Rosenthal, 2003).

In the 1970s, due to the declining conservation status of animals in the wild, governments established international and national regulations to protect endangered species and limit the commercial take from the wild (e.g. Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973; U.S. Department of the Interior - Endangered Species Act 1973). In the international zoo community, there was a growing awareness of the necessity of conservation measures to help mitigate the threats to biodiversity (Penn, Gusset & Dick, 2013 and Gipsos, 2013, both in this volume). Hence, cooperative animal management practices for husbandry, health (Bennett, 2013, this volume) and reproduction became imperative.

Inventory to information system
Ulysses (Ulie) S. Seal - a trained psychologist with a PhD in biochemistry and post-doctoral experience in endocrinology - became heavily involved in endangered species conservation while working on prostate cancer research at the Veteran’s Administration Medical Center in Minneapolis. In 1970, to facilitate multi-species endocrine research and in conjunction with the American Association of Zoo Veterinarians (AAZV), Ulie and his graduate student, Dale Makey, developed the SEAMAK ZOOGAD system (an early electronic database of blood values) for zoological data storage, retrieval and analysis. The results of their research were far less useful than expected because many of the zoo specimens could not be individually identified, or otherwise related to existing case-based veterinary records. Seal and Makey identified the need for detailed records of zoo specimens to be retained and updated in a global electronic database (Seal et al., 1976). By marking animals, creating sound specimen records and combining those in a shared dataset of current knowledge, zoos and aquariums could hope to sustain significant numbers of species for exhibit and conservation purposes. They could also become their own source of veterinary knowledge concerning wild species. In 1973, the American Association of Zoological Parks and Aquariums (AAAZPA) approved a proposal by Seal and Makey to develop an animal and endangered species inventory system based on SEAMAK ZOOGAD that could be used as an international database for managing captive animals. From this, the original International Species Inventory System (ISIS) was born. Essential to the success of this programme was an offer by Donald Bridgewater, Director, Minnesota Zoological Garden, to provide space for operation of the programme and to sponsor use of an available mainframe computer facility at the State of Minnesota Government Center. Initially, 55 zoos joined in response to the 1973 invitation to participate in ISIS. In 1974, ISIS officially began operations - with startup money from the US Dept of Interior, AAZP (now American Association of Zoos and Aquariums - AZA), American Association of Zoo Veterinarians (AAZV), and private foundations. The Minnesota Zoological Garden hosted the ISIS programme office for the next 15 years, and so the ISIS staffs were "zoo staff" technically, albeit self-supporting in their new role.

At first, paper pro-formas were filled out at the participating institutions for each specimen and mailed to ISIS for key-punch data entry. A magnetic tape was then taken to the State of Minnesota for use in the mainframe computer. This was an IBM System/370 Model 158, with a programme written in COBOL using the TOTAL database management system. The first mammal inventory was produced in May 1975, collating data for 12,156 living specimens from 92 zoos. As founder and director of ISIS, Seal never took a salary for his work. Nate Flesness, a graduate student of Ulie’s, also volunteered his time to help develop ISIS. In 1979, Ulie moved on to become Chairman of the IUCN/Species Survival Commission/Conservation Breeding Specialist Group (CBSG) and Nate then formally became Director of ISIS. In those early years, ISIS was comprised of only two staff members - Nate as Director and Kim Hastings as Data Entry Officer (later Office Manager). With growing importance and increasing worldwide membership, ISIS was becoming more than simply an animal inventory system. A database design ("ISIS 2") was started in ISIS in the direction of studybook-style tracking of animals. Hence, the name was

Milwaukee County Zoo historical ledgers used from 1893 to 1937
ISIS software development

Animal Records Keeping System
In 1983, the Wildlife Conservation Society/Bronx Zoo, Chicago Zoological Park, and US National Zoo along with funding from IMS, supported ISIS to write a simple database - pooling animal records for use in collection management. However, this did not facilitate easy extraction and analysis of information within the institution and especially between institutions.

In 1984, ISIS delivered ARKS1 (Animal Records Keeping System), written in dBase. It offered five outputs: consistency-checked data entry; a specimen report; a taxon report; an inventory report; and automated data submission to ISIS (Flesness, 2003). ARKS1 was a huge success with more than 100 institutions adopting the system. ARKS2 became the world standard for computerized zoological inventory records with added capacity to produce collection reports and an enclosure log. ISIS membership soared to over 330 institutions on six continents.

An updated ISIS 3 database was developed using FoxPro 2 DBMS and for the first time, information on one million specimens, living and dead, was stored and linked together in specimen histories, integrating data across the multiple institutions those animals may have visited. With the advent of Compact Disk (CD-ROM) technology, and as an extension to ARKS, ISIS in 1996 developed the first issue of a Specimen Reference tool for its members. Data on over 220,000 living specimens and 640,000 of their ancestors (representing 6,500 species held by 461 active ISIS member facilities) became easily accessible on the Specimen Reference CD-ROM. That same year, ISIS deployed ARKS 3 which added the capacity to keep historical data while increasing the number of data quality tools to ensure data accuracy. Early in 2000, ISIS released ISIS Collection Management System (CMS) for Windows alongside ARKS4 and use of the Specimen Reference CD-ROM. ARKS 4 could be used in any of 14 languages (English, Finnish, French, German, Hungarian, Italian, Japanese, Norwegian, Portuguese, Russian, Slovak, Spanish, Swedish and Ukrainian).

Medical Animal Records Keeping System
Lifetime medical records for animals are important for maintaining the health of individual animals and they serve to chronicle disease and medical problems as well as evaluate potential treatments at the species population level (Teare, 1991). Manual medical records systems used in most zoos until the mid 1980s did not facilitate easy extraction and analysis of information within the institution and especially between institutions. Throughout his (ongoing) career as a zoo veterinarian, J. Andrew Teare wrote or led the development of the various modules that made up the Medical Animal Records Keeping System – MedARKS. In 1985, the Chicago Zoological Society, Wildlife Conservation Society and Louisville Zoo approached ISIS with funding to start a medical records system. This was to be designed to make use of the animal inventory information in the recently released ARKS programme. By late 1986, the first module for anesthesia records was made available, with parasitology and prescription modules following between 1986 and 1988.

In 1988, with Andrew’s assistance, Cyril Shields-Teare took over the main responsibility for MedARKS programming and developed modules for: hematology, serum chemistry, sample storage (serum banking), clinical notes and pathology. Andrew Teare added radiology (1988) and between 1999 and 2010 developed new modules, including: regulated drug-tracking to meet Drug Enforcement Agency (USDEA) requirements; sample submission/tracking; and expansion of physiological measurements records. In 2010, over 90 zoos use MedARKS. Pooled data from MedARKS has generated the ISIS Physiological Values Reference Ranges CDs. These contain, for example, common hematology and blood chemistry test values, body temperature ranges and average weights for different age groups (primitive growth curves) for more than 1100 species.

Single Population Analysis and Records Keeping System

Until the 1970s, genetics was not considered an important factor in zoological management. Long-term captive breeding was not a major goal for most zoological institutions and records-keeping was therefore limited in that respect. Publication of landmark works on inbreeding in Przewalski’s horses (Flesness, 1977); and on genetic management and the dangers of inbreeding depression (Foote, 1977; Seal and Flesness, 1978) drew attention to critical issues in small population management. This also highlighted the necessity of collaboration between institutions for managing combined populations. Dr Tom Foose, AAAP Conservation Coordinator, working from the ISIS office and closely with Ulie Seal, developed the first AAAP Species Survival Plan (SSP) in 1981 for Siberian tiger (Panthera tigris altaica). Other breeding management programmes to manage captive populations of threatened species for genetic and demographic stability followed in AZA as well as in regional zoo associations in Europe, Australasia, Africa and Japan.

To cover the need for a computerized system to maintain a species database for breeding management, ISIS developed SPARKS (the Single Population Analysis and Record Keeping System). It was first issued in September 1989, based on a few already-existing local studbook programmes. ISIS programmers Paul Scobie, Laurie Bingaman, Lackey, and Steph Porter developed SPARKS with valuable input from Jon Ballou, Bob Lacy and Frank Prince. Later, SPARKS became the zoo and aquarium studbook software standard endorsed internationally by the World Association of Zoos and Aquariums (WAZA; see Penn, Guisset & Dick, 2013 and Gipps, 2013, both in this volume). In partnership with IUCNZ (the World Zoo Organization IUCNZ-WZO, now WAZA) and with the endorsement of the IUCN Species Survival Commission (Byers, 2013, this volume) ISIS assembled its database was stored on CD-ROM in 1996. The 2011 issue included 1540 SPARKS datasets from studbook keepers in 65 countries, plus over 3000 other documents, including 292 husbandry manuals.

Zoological Information Management System

By the end of the 20th century, ISIS had developed an extensive collaboration of zoos and aquariums that collectively entered their animal records for use in collection management, animal health and population management. However, ISIS worked with the capacity to keep track of these records with fast-evolving technology. Its central database - pooling animal records across institutions - had
Training in records-keeping

The first records-keeping training programmes were developed by non-ISIS staff. Karin Schwartz, then Registrar at the Milwaukee County Zoo, initiated development of the AZA Institutional Records-Keeping Course (IRK) through collaborations with the Midwest Registrar Group and AZA Conservation Academy. IRK, first taught in February 1998 as part of the AZA Professional Training Schools with Karin Schwartz and Glanvillous Fawcett (Lincoln Park Zoo) as Co-Administators. This training continues to be offered on an annual basis (Schwartz et al., 2011).

Similar records training workshops were also developed by the ARAZPA Records Group in Australasia and the British and Irish Zoo Association Records Group in the UK. With the deployment of the ZIMS application, ISIS established a training team led by Elisabeth Hurland (Technical Support and Training Director). With some assistance from other ISIS staff, online training modules were developed by Adrienne Miller, Training Content Developer on the ISIS Product Management Team, and by Josh Courteau, ISIS Training Manager. Training has now become an integral part of the services offered by ISIS in facilitating its global animal information system.

ISIS today

ISIS, as a non-profit organization, now sets the global standard in zoological data collection and analysis for its more than 800 member zoos and aquariums in over 80 countries. The ISIS global database contains information on 2.6 million animals (ca 15,000 taxa/10,000 species) and is constantly growing. ISIS has evolved from a small organization with a staff of one to an international class-organization that has developed a state of the art web-based animal information management system. In August 2009, ISIS was made available as a free tool to zoos that facilitate global animal information. The database has been used to estimate the number of threatened species maintained globally in zoological institutions.

In a study conducted between ISIS and researchers from Max Planck Institute for Demographic Research in Rostock, Germany, it was determined that roughly one out of seven threatened species on the planet can be found in a zoo or an aquarium (Conde et al., 2011). They stress that captive breeding in such institutions may be the only practical conservation option left for those species whose habitats are dwindling. Careful, accurate records-keeping is paramount for these animal management programmes. These efforts are facilitated by the use of the one global records database for animals under human care that has been developed through international collaboration and can be shared by all. In recent history, in part through the institution of ISIS, the nature and role of zoos and aquariums has been positively transformed in the direction of biodiversity conservation.

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References


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Nate Flesness

International Species Information System

Nate is ISIS Director of Science, 2009 to date and was Executive Director from 1979 - 2009, growing ISIS from 85 members to more than 800. He conducted graduate work in molecular genetics and evolutionary biology at the University of Pennsylvania, Chicago and Minnesota. He holds a Bachelor of Chemistry degree from the University of Minnesota.